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From mine to life cycle closure: towards a vision for the West Rand, Johannesburg

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Abstract

Mine closure needs reinvention. The notion of the lifecycle might be helpful for this purpose, as waste then becomes just another resource for the next productive process cycle. By closing lifecycles, e.g. soil, water and urban, a vision for the West Rand could be constructed that turns mine closure from a somewhat unwelcome and expensive obligation of restoration into a possibly strategic reinvention of the district. Instead of providing ad hoc and end-of-life solutions, mine closure then becomes part of a continuous transformation process that incrementally realizes the envisioned future and vocation of the land.

This paper discusses a design exploration – a methodology for Mine Closure – developed in parallel at the urban design studios of the Master of Urban Design (MUD) program at the University of the Witwatersrand, Johannesburg and the Master of Urbanism and Strategic Planning (MaUSP) and Master of Human Settlements (MaHS) programs of the KULeuven, Belgium. Both studios elaborated on the Master's thesis of Tahira Toffah. Through a methodology of research-by-design – a spatial exploration of integrating lifecycle closure – different visions were developed for the West Rand based on the water, soil and urban lifecycles.

Everything started and thus starts with the soil lifecycle. Instead of seeing the topographic alterations of on-going mining activities – underground, open-pit and tailings reprocessing – as an avoidable by-product of mining activities, soil displacement could be an imaginative project that sculptures the landscape in such a way that it recreates the necessary conditions to bring back wildlife to the mining belt. The sculptured undulating landscape would potentially create places to drink, places to hide and sleep, accentuated by vegetation that simultaneously remediates the polluted soils. A new urban national park would emerge ex novo.

The water lifecycle in the West Rand demonstrates several misbalances. An average of 27 Ml/day of acid mine drainage is being pumped out from the mine shafts and discharged in elementary treatment facilities; yet effective treatment of this excess water (in a region with water shortage) could systematically irrigate the downstream district with balanced amounts of clean water, thereby generating a new production landscape. In so doing, the mining belt adds high value. Intensively maintained cropland could provide a significant portion of Johannesburg's increasing food demands while creating employment opportunities. In short, it could generate an oasis in the arid landscape.

The urban lifecycle in this case consists of the reversal of the social disjunctions that have taken place here over time. The West Rand mining belt sits in between the township Kagiso and (the

Victorian-era laid out) Krugersdorp, and as such, it could, through a transformation process, be turned from a divide into a common space where people work, exercise, educate; it could become the place of exchange. Specifically targeted strategic interventions that serve the urban fabric could create these common spaces.

The idea of the cycle implies an immediate as well as a continuous effort. In order for such an operation to be successful, one must act immediately and never stop acting. In this conception there is, by definition, no end nor even mine closure, but rather a continuous innovation and design of intertwining lifecycles – soil, water, urban, etc. – that define mining and other activities on the land and deliver the means with which one can build a vision.

Résumé

Il convient de réinventer la fermeture des mines. La notion du cycle de vie pourrait être utile à cette fin, puisque les déchets ne deviennent alors qu'une autre ressource pour le prochain cycle de processus de production. En fermant les cycles de vie, e.g. du sol, de l'eau et de la ville, il serait possible de construire une vision pour le West Rand qui changerait la fermeture de la mine d'une quelconque l'obligation de restauration malvenue et coûteuse en une réinvention stratégique possible du district. Au lieu de fournir des solutions ad hoc et de fin de vie, la fermeture de la mine deviendrait alors une partie d'un processus continu de transformation qui réaliserait progressivement l'avenir et la vocation envisageables du terrain.

Cet article examine une exploration de conception – une méthodologie pour la fermeture de mine – développée en parallèle au studio de design urbain du programme de Master en Design Urbain (MUD) à l'Université du Witwatersrand à Johannesburg et le Master d'urbanisme et de planification stratégique (MaUSP) et les programmes de Master en établissements humains (DAMM) de la KULeuven, en Belgique. Les deux studios se sont développés selon le mémoire de maîtrise de Tahira Toffah. Grâce à une méthodologie de recherche-par-conception – une exploration spatiale de l'intégration d'une fermeture de cycle de vie – des visions différentes ont été développées pour le West Rand basées sur l'eau, la terre et les cycles de vie urbaines.

Tout a commencé et donc commence par le cycle de vie de la terre. Au lieu de voir les modifications topographiques des activités minières en cours – souterraines, à ciel ouvert et retraitement de résidus – comme un produit évitable des activités minières, le déplacement de la terre pourrait être un projet imaginatif qui sculpte le paysage de telle manière à recréer les conditions nécessaires pour ramener la faune dans la ceinture minière. Le paysage vallonné et sculpté peut créer des endroits où boire, des endroits où s'abriter et dormir, qui peut renforcer la végétation qui assainit simultanément les sols pollués. Un nouveau parc national urbain aille émerger ex novo.

Le cycle de vie de l'eau dans le West Rand montre plusieurs déséquilibres. Une moyenne de 27 Ml/jour de drainage minier acide est pompée des puits de mine et déchargée dans des installations de traitement élémentaire; alors qu'un traitement efficace de cet excédent d'eau (dans une région où il y a pénurie d'eau) pourrait irriguer systématiquement le district en aval avec des quantités équilibrées d'eau propre, générant ainsi un nouveau paysage de production. Ce faisant, la ceinture minière prend une grande valeur. Des terrains cultivés intensivement pourraient fournir une partie importante de la demande alimentaire croissante de Johannesburg, tout en créant des possibilités d'emploi. En bref, on pourrait générer une oasis dans le paysage aride.

Dans ce cas, le cycle de vie urbaine renvoie à une inversion des disjonctions sociales qui ont eu lieu ici au fil du temps. La ceinture minière du West Rand se trouve entre le township de Kagiso et de Krugersdorp (le dernier disposé à l'ère victorienne); et de ce fait elle peut, grâce à un processus de transformation, être changée d'un espace de séparation divisé en espace de partage commun où les gens travaillent, font de l'exercice, éduquent; elle peut devenir le lieu d'échange. Des interventions stratégiques ciblées qui servent le tissu urbain peuvent créer ces espaces communs.

L'idée du cycle demande donc un effort immédiat et continu. Afin que cette opération réussisse, il faut agir immédiatement et ne jamais cesser d'agir. Par définition, dans ce concept il n'y a pas de fin, n'y pas même de fermeture de mine, plutôt une innovation continue et la conception de cycles de vie qui s'imbriquent les uns dans les autres – terre, eau, ville, etc. – qui définissent les activités minières et autres sur le terrain et donne le ton sur lequel on peut bâtir une vision.

1 Introduction – situating the case

The Witwatersrand region is constructed and defined by its mining history (Toffah 2012, Harrison and Zack 2012). This identity and history is embodied in the mounds of golden-yellow residues scattered across its landscape. This landscape is – despite the fact that most mines ceased underground operations in the 1970s – under continuous transformation, through programs of removal, projects of extraction of residual ores, the intrusion of informal settlements, and the redevelopment of land for business parks, etc. (Bobbins 2013). A relocation program – fuelled by market, legislative and environmental interests – has led to the relocation of most dumps and tailings to 'super dumps' on the edges of the region (DRD Gold 2014, Sibanye Gold 2012).

The Witwatersrand region suffers today from the environmental consequences of over a century of mining and processing of ore, resulting in landscape that is polluted both above and below ground (Gauteng Department of Agriculture Environment and Conservation 2008, McCarthy 2010). These mine residues are the source of airborne and waterborne pollution, as well as soil contamination that can have an ongoing impact. Acid Mine Drainage (AMD) is formed within the tailings residues and in underground workings, and at times decants into the water systems. Containment and treatment in the East and West Rand basins is being dealt with mechanistically, but no sustainable long-term solution has been put in place. The mining landscape of the Witwatersrand Basin is therefore seen as one of the major threats to the sustainable development of the region.

Mining, water and environmental legislation is in place in South Africa. This paper acknowledges this framework, but argues for an approach that goes beyond the aim of most legislation which calls for the neutralisation of the impact of waste. It suggests, rather, the introduction of the tools and strategies of landscape urbanism as a way to cut across sectoral interest and technologies, time scales and even ownerships, in order to envisage a new future for the mining belt.

The mining belt was developed in the 1950s as a buffer zone between non-white townships in the South and Central regions (Soweto, Lenasia, Kagiso, etc.) and the mostly white and more affluent northern region and South. The mining belt is the 'third area' that residents from antagonistic areas shared a place of work where an exchange, often minimal, nevertheless occurred. These mining belt sites have been envisaged in the past as sites for redevelopment (at least those areas in which reclamation has already taken place). Where this has taken place, the uses have been typical of large open spaces near cities: warehousing, container ports and informal settlements.

We argue that the relationship between spatial development under apartheid and the location of mining justifies the use of this land instead as a retributive landscape, in which the economic inequality and social uprooting of apartheid should be met with a project of spatial justice. This requires, in turn, a new, design-led attitude towards the landscape, in which its environmental pollution is treated in ways that also deal with social and economic ills.

This requires a fundamental reconfiguration of the metropolitan landscape, that rethinks the structure as well as the components of the city. We argue that the zone of the mining belt can be seen as the vacant heart of the city; a heart that in the past was a divider, then a diseased zone. With different perspectives it could now be turned into a connector, a mediator, through design-based rethinking of the processes of environmental remediation.

1.1 Landscape urbanism (De Meulder and Shannon 2010, Shannon and De Meulder 2013, Shannon et al. 2008, De Meulder and Shannon 2011)

The conventional approach to mining belt reclamation starts from the side of the disturber and aspires for their processes can be contained until they reach a status of minimal waste. These efforts attempt to stabilise ecological systems. They aspire to turn dynamic processes into a static situation. Instead, the landscape as a dynamic system of processes and cycles needs to become the main driver of the mining belt reclamation. Landscape urbanism – looking at and designing a zone from and with the logics of the landscape – is proposed as a continuous design effort and as a methodology to reclaim the mining belt. Instead of considering the mining belt as an undesirable outcome of mining activities, it could be reconsidered as a string of open ends in the broken soil and water cycles. Closing these cycles as much as possible by exploiting this landscape's opportunities can possibly lead to a more stable long-term reclamation process, rather than ad-hoc mine closure solutions. In this way, the retribution due for the damage of extraction becomes repaid, as investments in future development.

Urban design as a discipline, and specifically landscape urbanism, has the capacity to contribute to the development of the necessary steps in the closure of the cycles and consequently to the upgrade of the spatially neglected mining belt. Two key aspects of the discipline make landscape urbanism useful. Firstly, when talking about the mining belt, it is above all a physical space which is perforce the prime theatre of urbanism: intervening in space, translating spatially and designing complex processes. Secondly, urbanism is an integrative discipline. It does not pretend to have all the solutions to complex matters crossing various disciplines, but, as design discipline, it is able to integrate and mediate between engineering, ecology, policy, etc.

In short, we test the hypothesis that landscape logics and lifecycle closure are able to provide solutions for a variety of issues involving various actors. Consequently, this proposition does not only reclaim the mining belt as a space, but equally becomes the platform of negotiation between various stakeholders and interests.

1.2 West Rand as a case study

The hypothesis of this paper is that landscape urbanism – urban practice through the logics of the landscape, whether this is considered natural or artificial – has some capacity to address the vacancy and pollution of the mining belt. This design approach works with landscape strategies such as water structures, afforestation, (urban) agriculture and nature re-instauration. It proposes a basis for the future functioning, not of the mining sites alone, but of the central mining belt and the whole southern half of the metropolitan plane that falls within the catchment area of the mining water overflows. As landscape features determine the approach, the water catchment area evidently becomes the basic frame.

Gold mining has been omnipresent in Johannesburg and was roughly organised in three basins – the West, Central and East Rand – that have distinct characteristics.

This paper discusses a vision for reclaiming the post-mining belt in the West Rand basin that has been developed in the Master of Urbanism and Spatial Planning and Master of Human Settlements programmes at the University of Leuven, Belgium (KULeuven) in collaboration with the Master of Urban Design programme of the University of Witwatersrand, Johannesburg, and for which the Master's thesis of Tahira Toffah served as a basis (Toffah 2012, Toffah 2013). Further input was obtained from the Centre for Sustainability in Mining at the University of Witwatersrand, Johannesburg, and assistance from various institutions such as the Gauteng City-Region Observatory and Mintails Pty Ltd, the main active mining company in the West Rand. The West Rand was chosen as a case due to its pertinent problems and opportunities. The West Rand mine basin decanted in 2002 making it the first of the three basins to enter an absolutely critical state of AMD-related disaster. The reduction of the mine industry to a minimal work force has also resulted in a decrease of industrial activities, and thus the need for alternative economies for the rather poor population. Despite this, the main mining company present in the West Rand – Mintails, with Anthony Turton as main contact and driver of thinking about post-mining visions – was quite open for communication and input concerning mine closure, allowing for close contact and an insight into mining logic. In addition, the West Rand lies on the edge of the grand metropolitan Johannesburg inside a fantastic landscape with tourism potential. Both practical and visionary arguments made the West Rand a perfect case study.

The vision for reclaiming the West Rand is organized through three main concepts and through the methodology of urban design: closing, respectively, the soil and water cycles and 'upcycling' the urban condition.

2 Introduction into lifecycle closure

Three main ideas are combined in the 'lifecycle closure' concept:

2.1 Embracing mine logics

It is important to understand that mine activities themselves give the clues for reclaiming the mining belt. It is unproductive to go against the nature of the activities, or to think to "counteract" them. With the best of intentions, most mine closure measures consist of stabilizing problems or returning situations to their original and less hazardous state. This static state in a dynamic landscape seems doomed to fail. By classifying these activities within the lifecycle, they are reframed and hopefully optimized to serve the cycle. It is an act of reverse engineering with a paradoxical outcome. By embracing the mine logics by fully understanding their functioning and thus potential, the way mining is executed can be fundamentally rethought. The mining landscape would therefore enter a new productive cycle that is fundamentally different from the conventional mine era; but it is not reconstructive surgery attempting to return to a pre-mining state.

2.2 Producing a vision

There is a need to go beyond the engineering. Reverse engineering is a step towards reclaiming the landscape, but it also implies transformation of the landscape. Instead of reconstructive engineering, the process aims to simultaneously unfold a vision. The vision is not a mechanism, but rather forms the frame to which all actions refer and are evaluated within. More importantly, the vision is projective: it generates a perspective, a view of what the mining belt could become without the mining. A vision aids the imagination, and an important aspect of reclaiming the mining belt is exactly this: changing the mindset of people, making them disposed to envision a new future.

2.3 Non-linear, complex solutions

Lifecycle closures and urban upcycling are necessarily intertwined and inseparable. Lifecycles can, for reasons of clarity, be separated theoretically, but, at the end of the day, in practice they flow into and influence each other. The generally applied one-on-one linear solutions must be moved away from. This makes the notion of urban upcycling so important. The urban fabric, and thus its population, will play a crucial role in the lifecycle closure. Without their involvement to maintain both soil and water cycle, there cannot be any closure.

3 Closing the soil cycle – urban wildlife park

3.1 The disrupted soil cycle

The idea of the soil cycle, represented in Figure 1, is fundamental. The three main types of mining operations – underground, open-pit and hydraulic mining – lead to the different ways in which the displaced soil is placed. A large amount of soil is not part of a cyclic model, and is regarded as a topographic waste. The super dump is an open-ended solution and cannot be considered to be part of the soil cycle. The unstable open-ended situation in the West Rand today is the direct consequence of soil displacements. The process starts as follows: Large, disproportional amounts of rock and soil are disrupted from their stable composition, in order that precious minerals may be extracted and concentrated. The vastness of this disruption can barely be comprehended by a human being. Polluted dumps many kilometres in size – e.g. 240 dams over 44,000 ha (Mphephu 2002) – spread out in seemingly random positions – are thought to be the logical outcome of extraction methods that combine optimal economic and technical possibilities. This has, however, led to a number of open-ended unsustainable situations.

The decomposition of soil in order to extract minerals liberates not only the precious metals, but also harmful elements, such as sulphur (from pyrite), aluminium, cadmium, cobalt and nickel (Oelofse et al. 2007, p. 5) and in the case of the West Rand, also uranium. During decades of mining, these pollutants were spread around a vast region, as an unavoidable waste product, without considering ecological impacts. It appears that only after the enactment of the Minerals Act 1991 (Act 50 of 1991), attention was drawn to the multiple environmental impacts and responsibilities of mining operations (Swart 2003).

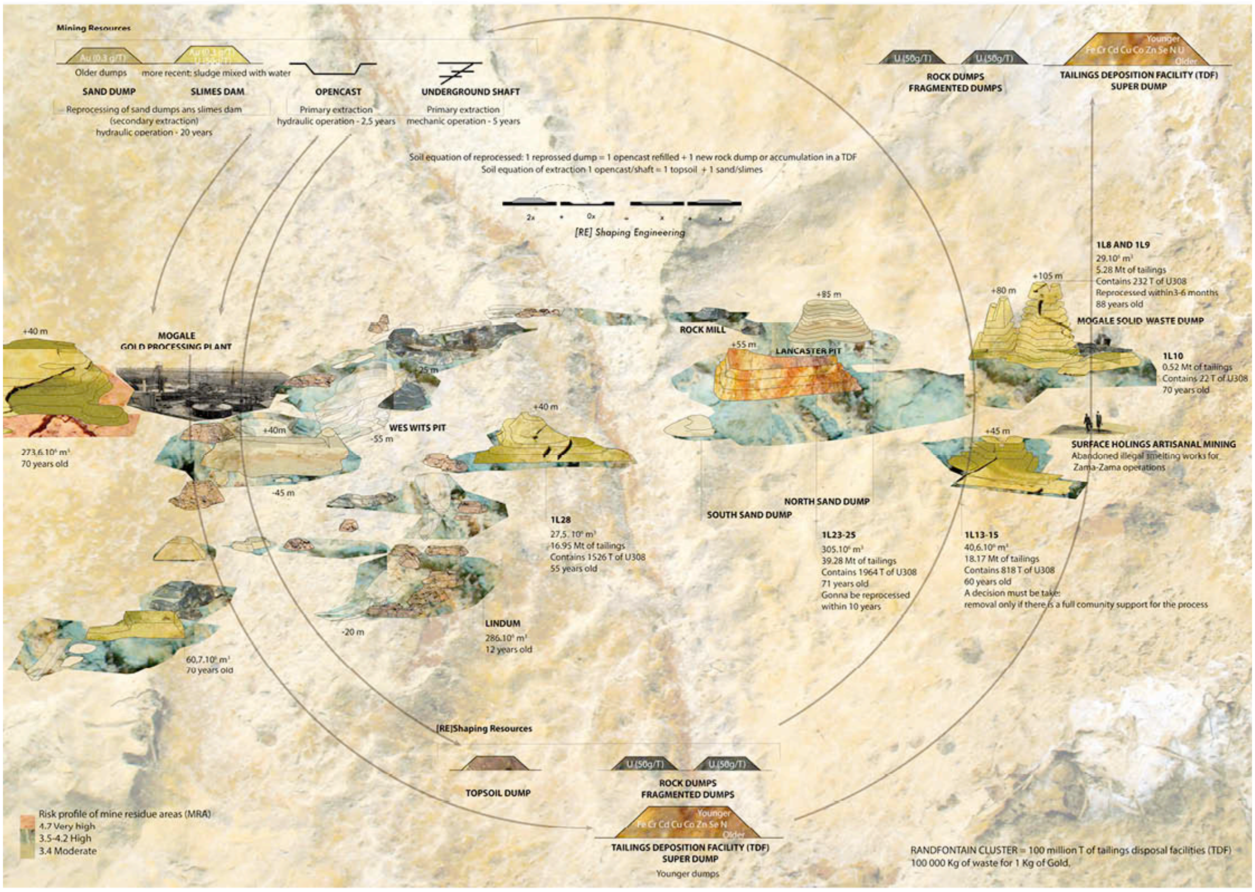

Figure 1 Disrupted soil cycle

Besides these generally observed pollutants, the rock, sand and soil itself is another by-product of mining. The decomposition of the rock that previously kept the hazardous elements stably fixed also results in an excess of ground. Most of the extracted material from underground mining remains on the surface – although now some experiments have been performed on dump tailings inside mine shafts, to balance the pH level of the water. For open-pit mining, the extracted ground doubles in volume once blasted from its compound (Turton 2014). This available volume of ground is usually considered to be scars in the landscape. Only occasionally, they are appropriated, e.g. as an open air cinema.

The notion of the super dump (DRD Gold 2014, Sibanye Gold 2012) – gathering all the scattered tailings dams on centralised and consequently huge sites after reprocessing – reveals that the main problem is that of concentrating and stabilizing the pollution and soil. Furthermore, their existence seems to justify the continuation of ground movements from mining, as has happened for decades. It can however be argued that there is no such thing as fixation, nor stabilization, of pollution. Since the tailings dams are automatically part of the dynamics of the landscape – e.g. rain, wind, animals, that wash, blow and transport – the pollution will become uncontrollably mobile again with time, as has been reported for the already existing dumps (Oelofse et al. 2007, p. 1). The soil cycle is thus continuously left broken without considering cycling it towards a more dynamic and thus resilient purpose. The Chamber of Mines of South Africa does mention the use of soil for topographic purposes (Africa/Coaltech 2006, p. 27), but mainly from the perspective of how technical solutions can stabilize the soil, considering for example, the right slopes.

Different dumps – rock, sand and 'waste' dumps, slimes dams and top soil heaps – lie scattered over the vast territory of the West Rand. They are also remnants of mining activity, of future resources. Most of them are not in their final resting place, since they will be either reprocessed for residual gold, or used for refilling the holes of open pit mining. In the latter we can speak of reconstructive landscaping. In the case of the reprocessing, the future path of the soil is clear: the material will pass through the gold production plant in the West (Mintails facility), through hydraulic mining and pipes. This process will take decades and will provide a stable income for the mining company. For practical and economic reasons, the starting point of most of the soil operations evidently has to be here.

The proposed superdumps are a threat to ecology due to the soil's travel distance, the possible leakage from the pipes and the local impact of the superdumps. The extracted soil should stay close to its origin as far as possible, and the pollution problems should be treated on site. Since the movement of soil is already quite well organized in the West Rand, the existing infrastructure could be reinstated for remediation.

3.2 Soil remediation

The reuse of the soils is highly conditional. The soils contains many pollutants, due to their contact with air and water and the processing chemicals of the gold production plant, but the soils – finally sand or ashes – are also non-fertile, with very little organic material, since they have never been exposed to organic waste.

Both conditions can be tackled by phytoremediation technologies. In the project for the West Rand, a remediation mechanism is envisioned that treats and fertilizes soil in the long term. After gold is extracted, the soil ends up in big basins. Once the necessary pollution analysis is performed, the appropriate vegetation can be chosen, which extracts the identified pollutants, and in a second step, introduces organic waste material into the soil. After treatment, the soil can be redistributed wherever needed. In other instances, polluted soil is brought back to the Mine Residue Areas, which are already polluted. These soils are planted with vegetation as an act of phyto-stabilization, where the goal is not to extract the pollution, but fixate it.

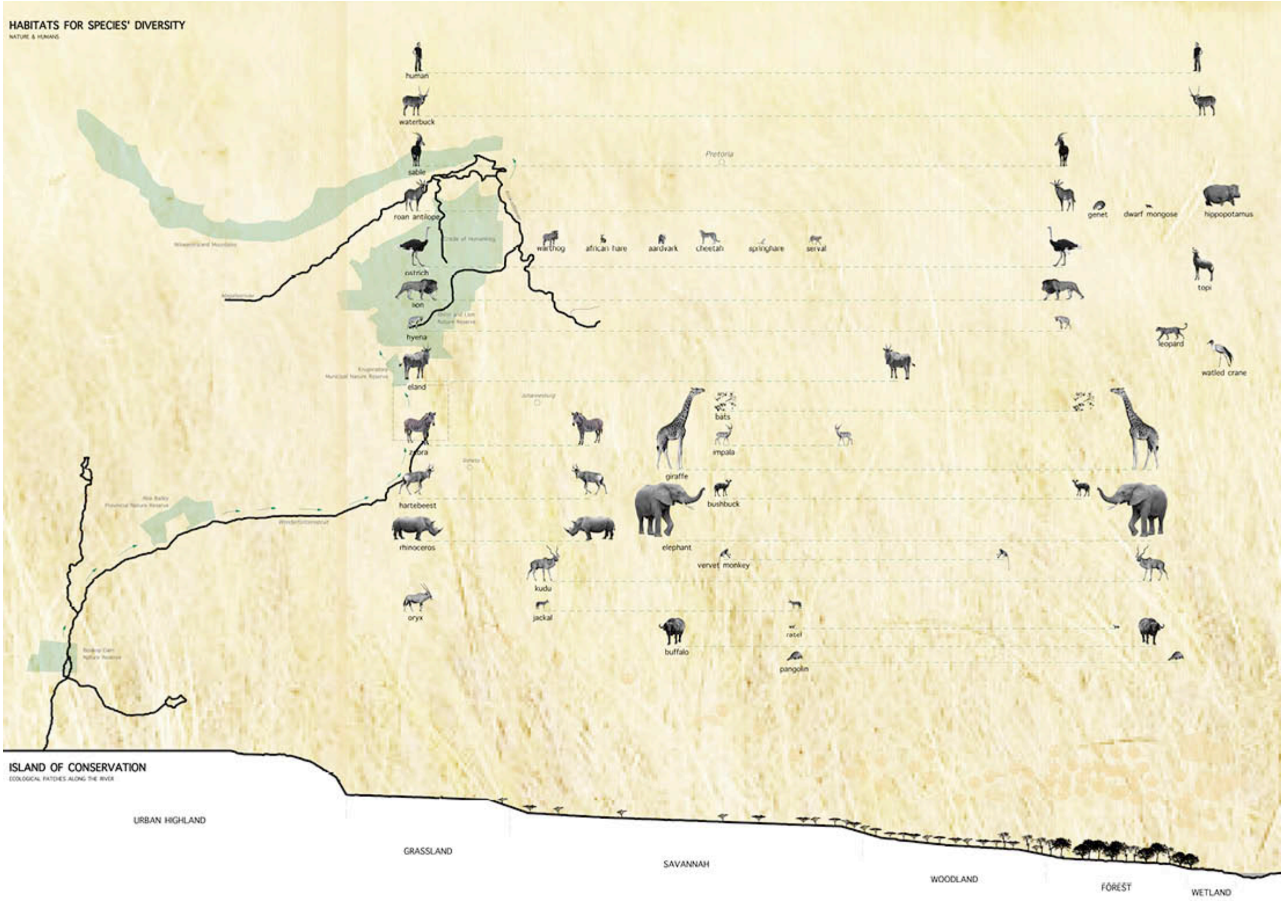

Figure 2 A vision: an urban wildlife park for the West Rand

3.3 Vision: an urban wildlife park

The West Rand has a unique position in the vast Witwatersrand. The West Rand is not urban, rather rural and embedded in the majestic landscape that characterizes South Africa so much. Even the slightly denser Krugersdorp doesn't really transmit an urban vibe; at most a certain provinciality. In the vicinity there are some important wildlife resorts and botanical gardens.

The vision for the West Rand anchors itself on this identity. The West Rand, crucially located on a North-South ecological corridor, has the capacity to become a new type of Wildlife Park, where contact with humans is not necessarily organized by fences and gates. The West Rand could become a flowing landscape, creating the necessary north-south migration path for animal and plant species, planted with an indigenous vegetation that recreates the original landscape of savannah, woodlands, and bush lands (Figure 2). A high variety and continuity of landscape allows for different habitats for a wide range of animals. This landscape can even penetrate the urban fabric of Kagiso and Krugersdorp.

Closing the soil cycle realizes the reclamation of the mining belt; while keeping and remediating the soil allows for the sculpting of the topography. High and low, steep or gentle slopes, wet or dry, are all conditions that can be controlled by modelling the terrain. It is as good as a free commodity, present in millions of cubic metres.

A quick analysis of the position of the West Rand in the ecological system shows the potential for linking the Tweelopiesspruit and the Wonderfonteinspruit, as in Figure 3. This cross-watershed connection of two valleys would create a corridor that would allow animals to follow the water. To create this valley condition with gentle slopes, a mountain would need to be created to retain the water. Designed following proper design parameters to avoid erosion, these features could accentuate the landscape and harmonize with them. Between high and low, there is generated a multitude of different conditions and habitats, through different planting policies, variations in slopes and the presence of wet and dry conditions.

Figure 3 A vision: an urban wildlife park for the West Rand

The urban national wildlife park could capitalize on the tourism vocation that the West Rand is already experiencing, while distinguishing itself by a more sustainable approach to the contact between man and wildlife. Rather than a zoo, it would attempt to enhance a lifestyle that is often linked to the South African identity.

3.4 Soil cycle closure

If the soil is cycled through a system of phytoremediation and new topographic changes, instead of being a waste product that needs to be stored, it becomes a commodity that could be used to build a new urban wildlife park. The realization of this vision is one of a long duration, but can be started today, and in addition, it is flexible. The sculpting can be a continuous design effort, adding to the richness of the landscape. In comparison with the current intense open-ended philosophy of mine closure, the soil cycle closure requires an effort that is spread out over a long time. In this scenario, the economy of mining can produce this vision, but will be gradually replaced by smaller scale economies with soil as the main commodity. Figure 4 suggests a piece of the remediation mechanism and artificial mountain. The temporary mountain on the left of the figure organizes the co-existence of human and animal in the wildlife park and creates the ecological corridor. On the right is an area of remediation works which is designed to temporarily store, remediate and introduce organic material into the soil. Its organization is based on rational actions of soil delivery and extraction, optimal remediation, and soil availability.

4 Closing the water cycle – articulating the urban wildlife park

4.1 The disrupted water cycle

The disrupted soil cycle leads to the disruption of the water cycle, as shown in Figure 5. The exposure of pyrite to air and water creates acid water in both dumps and underground (Johnson and Hallberg 2005). This leads to an underground basin of acid water that is continuously charged by rainwater and underground aquifers. The specific physical structure of the underground mines defines the resistance of the water movement, and leads to the identification of the three main basins in the Witwatersrand mining belt. Decommissioned mine pumps – in the case of mine closures – cause a steady rise of the underground water level. At a certain height, the AMD will decant into the surface river system. In the West Rand, this occurred in 2002 (Fourie 2006a, p. 4). The current pumping and treatment system prevents uncontrolled AMD decanting, but the purification is rather elementary: it only deals with the pH level, the heavy metals and sometimes also the salts. This rudimentary treated water is then discharged in the river system. The water is – in this dry region suffering from water shortage – actually not seen as a potentially useable commodity, as a resource. It is treated as waste that has to be disposed of.

Figure 4 From left to right: a strip of urban design, showing topographic landscape alterations

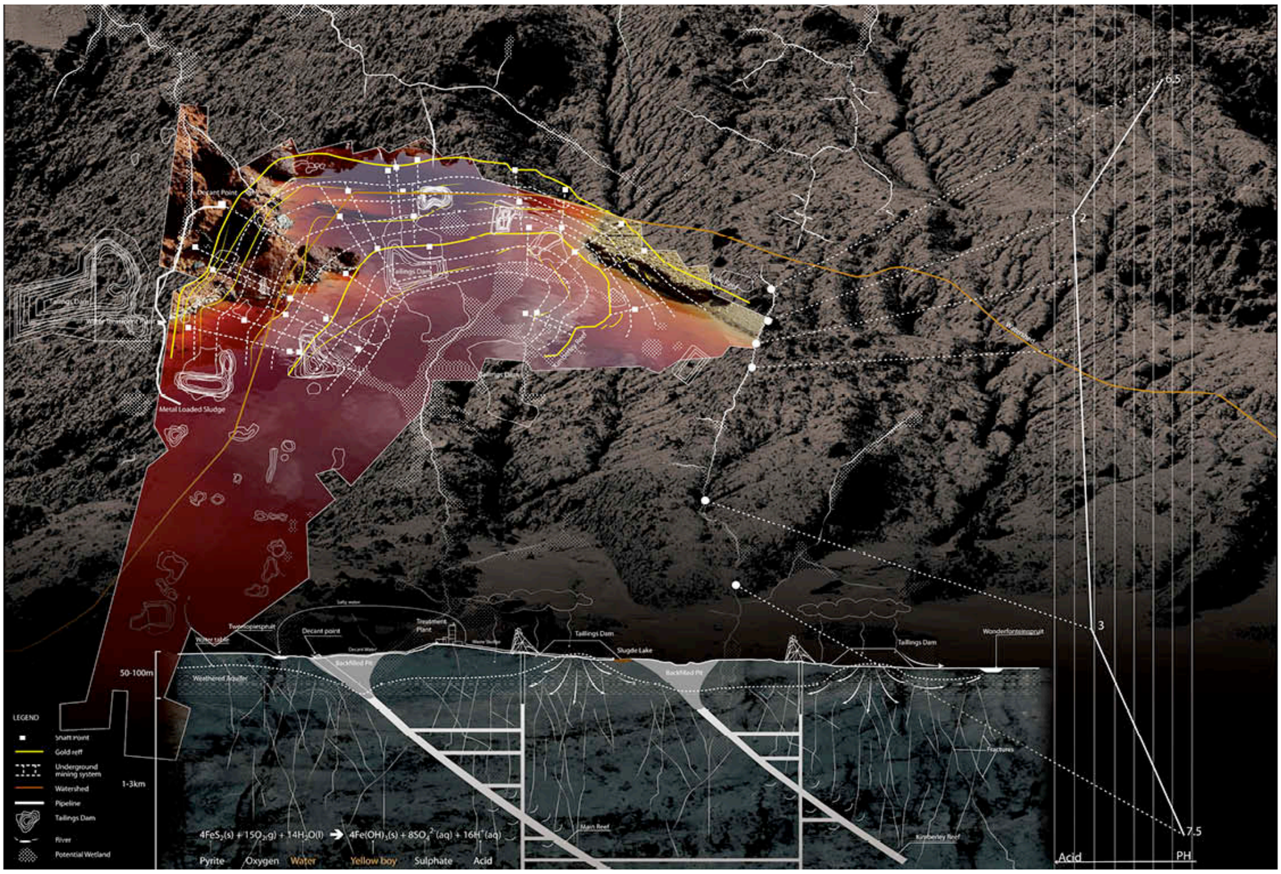

Figure 5 Disrupted water cycle in the West Rand basin

The water provision for the West Rand (and Johannesburg) comes from the Vaal Dam and Lesotho Water Project (Figure 6). Water travels tens of kilometres to reach Johannesburg and the West Rand (ORASECOM 2013, Rand Water 2014). The industrial mine water on the other side seeps into the underground and mixes with rainwater to form AMD. This artificial underground basin functions similarly to an aquifer, but intersects both aquifer and surface river basins, creating bridges between clean and polluted water. Water seepage from mining in the West Rand occurs mainly in the southern Vaal River basin, but decants in the North-oriented Limpopo River basin. This decant is now avoided by pumping, and is directed towards the Vaal River system again, increasing the natural water volumes and discharging water that contains salts which possibly affect the downstream water irrigation systems towards the Northern Cape.

In summary, the West Rand is using and discharging huge amounts of water with various concentrations of pollution. The water cycle is left open, since even with partial remediation of the pollution, the water volumes are highly artificial and often problematic in relation to their natural condition (Fourie 2006, p.5), leading to rising of the water level, increasing pollution, and groundwater depletion. Water levels in underground mining will continue to rise for an unknown period of time. In other words, massive amounts of water will have to be pumped out for a considerable time.

After AMD started being decanted in 2002, the pumps have been restarted and the AMD is being treated with high density sludge treatment. Lime is mixed with the acid water to neutralize the pH. When the pH goes above 5 the heavy metals precipitate out of solution into the sediment and are no longer mobile (Bruno et al. 1998). However, the salts remain in the water and affect the downstream Vaal River. The current plant also lacks capacity when heavy rains occur. Amidst this failing engineering, some improvements of the water quality have nevertheless been noticed where the water flows through natural wetlands. The slow pace of the water and anaerobic conditions allow the wetlands to precipitate out the metals. Yet, uncontrolled decant continues to occur and the natural wetlands are unable to render the AMD harmless.

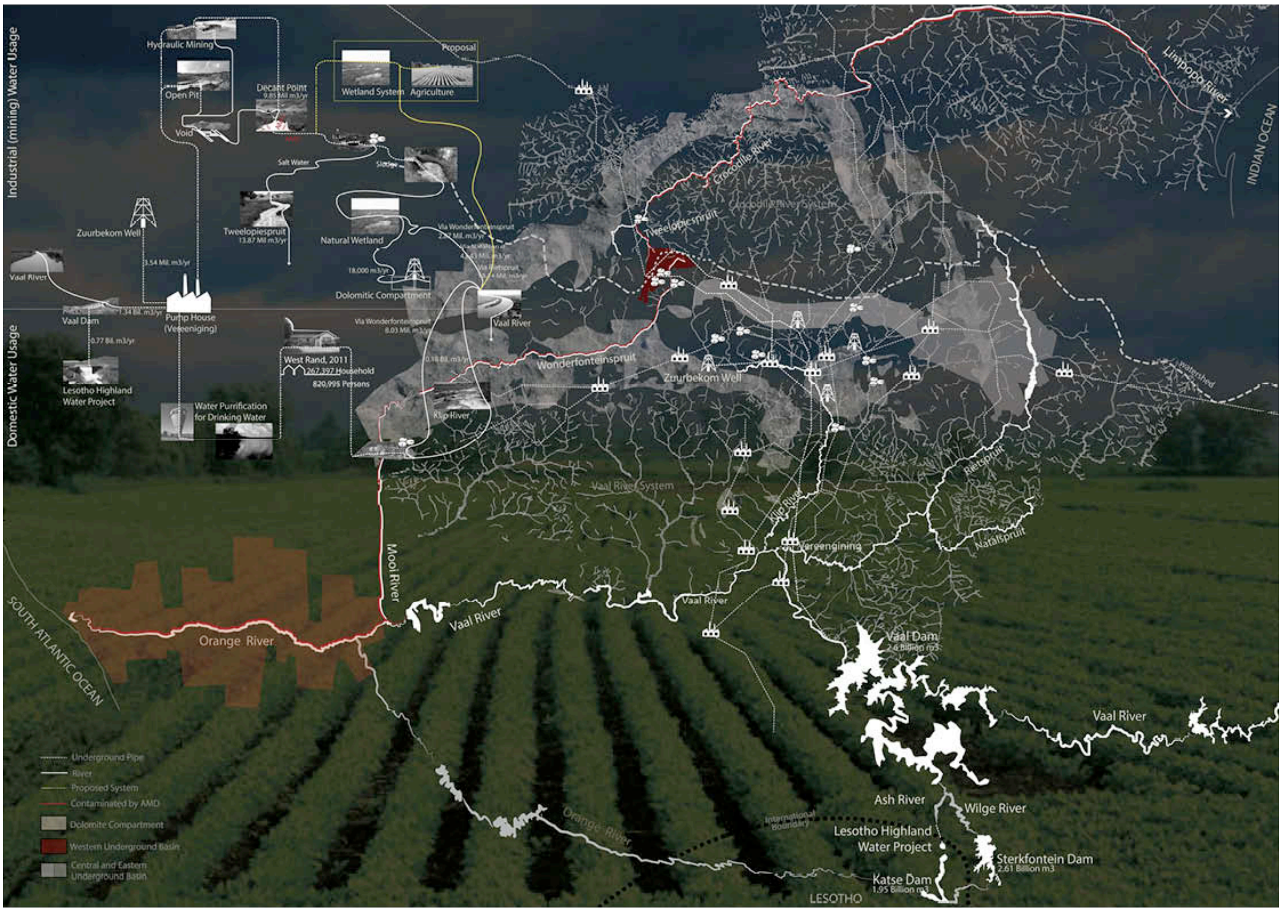

Figure 6 Disrupted water cycle on the macro scale

4.2 Water remediation

Natural wetlands have proven their value for precipitating some metals out of the water, but they are incapable of treating all the hazardous materials in the water. Constructed wetlands have also proven to be somewhat successful, although this type of treatment system has some disadvantages such as the fluctuating outcomes, depending on weather conditions and actual pollutants in the water. Yet in comparison to treatment plants, they provide many benefits for the economy, ecology, society and landscape (Ford 2003). In what follows, a remediation strategy is unfolded in which constructed wetlands have a key role.

The first approach in the remediation strategy is the pumping tactics. Currently water is pumped up from one shaft, making the system highly dependent on it. By decentralizing the pumping, a more safe and resilient system can be installed. The abundant presence of shafts allows for a dispersed extraction of water. If a shaft close to the watershed line between Limpopo and Vaal River is selected, the water would undergo gravitational flow downhill. The constructed wetlands are also installed as high as possible, to enhance irrigated agriculture on as much downhill land as possible; while only counting on gravity and systematically avoiding theft-prone technologies like pumps and tubes.

The remediation strategy builds on the examples of AMD and ART in Vintodale, Pennsylvania (AMD&ART 2003 – 2009, 2014) and the Wise Legacy Wetland project of the campus of the University of Virginia-Wise. (Comp 2004). Both are affected with AMD from former coal mining. Although the specific pollutants and therefore the constructed wetlands are different from the situation in the West Rand, the methodology and calculation nevertheless give a rough idea of how to design the natural water remediation. A four-step constructed wetland system remediates the water through an acid pool where the AMD is gathered and stored (Figure 7). This basin also buffers the fluctuating flows through the wetland treatment ponds and three continuous ponds with specific plants and compost. The water runs through it slowly and horizontally; through a vertical flow pond in which the water flows vertically through a layer of organic material and limestone, raising the pH; into a settling pond where iron oxides are exposed to oxygen and precipitate (AMD&ART 2003 – 2009, 2014). Afterwards the water can be used for a variety of purposes, amongst which are high added-value crops or the introduction of water in Kagiso.

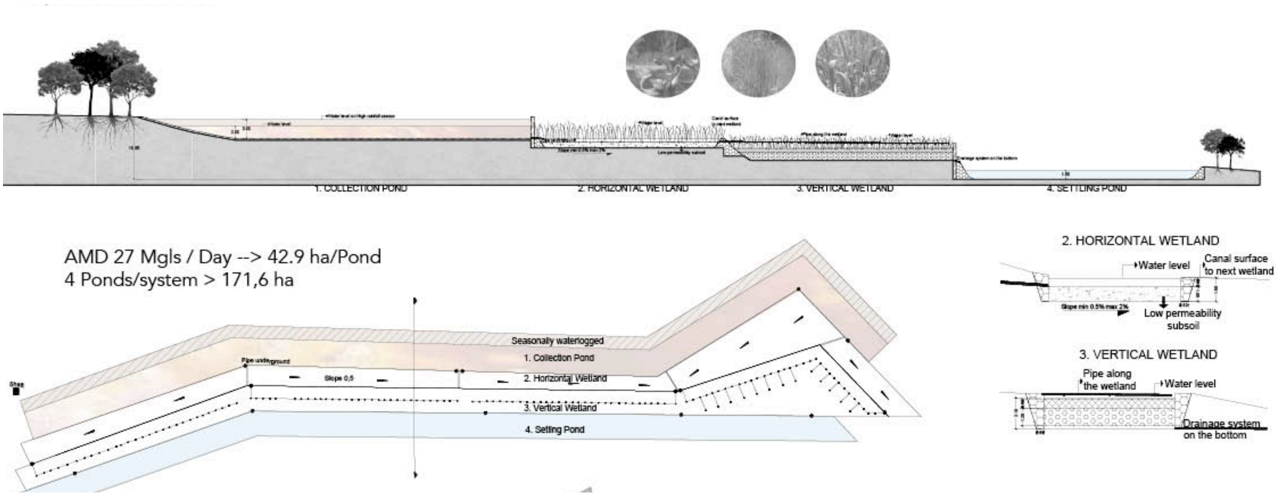

Figure 7 A four-step constructed wetland system is introduced in the water cycle to re-cycle and re-use the water on site: 1. Acid water pond, 2. Horizontal wetland system, 3. Vertical wetland system, 4. Settling pond

Based on Demchak et al. (2001) for Virginia, 1 m^2 treats about 63 l/day AMD. Treatment of an average AMD of 27 Ml/day would consequently require 43 ha for each step of the wetland. Considering the majestic size of the mining belt, this amount of land is rather marginal. This is however only a very rough and first estimation. The heavy metals in the AMD in the West Rand are indeed somewhat different from those in the example. Nevertheless, the proposed solution is likely to be made applicable by altering the design parameters of the wetland and by careful testing of appropriate plants. It could become larger, or smaller, with different plants or compost. The right solution can only be found by carrying out pilot projects. What matters is that there is abundant space available and the possibility for such a system to be developed and optimized in the mining belt. Figure 8 shows the location of the constructed wetland system in relation to topography and shaft location. The wetland systems (from light grey to black) are located close to the watershed line and connect to specific shafts where water is pumped out of the mines (red dots). From there the natural topography allows for gravitational irrigation of the agricultural plots.

4.3 Vision: an agricultural oasis

Besides the abundance of soil, the abundance of water is probably even more impressive. Not less than an average of 27 Ml/day drains from the mines in the form of AMD, and this is within the context of the semi-arid landscape of the West Rand. The current treatment of the AMD, without sufficient capacity in the rainy season, discharges all of this 'waste'-water wastefully into the Vaal River where in fact it does not naturally belong.

A vision is constructed that is based on the assumption that an abundance of water of suitable quality can provide the opportunity for intensive agricultural production in the immediate proximity of one of the largest African megalopolises. It does not need to be said that such an amount of water, albeit artificial, should not be wasted but rather recycled in order to benefit the relatively poor and unemployed population. There is in any case a fairly constant and voluminous flow of water available, and this will be the case for a very long – be it unknown – period of time.

The treated water can generate an oasis in the semi-arid landscape constructed by closing the soil cycle. The agricultural fields follow the logics of the landscape. The organization of the plots is based on the slope and direction of the earth canal system constructed by operations of "cut and fill", where the excavated soil is used to construct small dams or higher land. Former mine workers or unemployed migrants can gradually become farmers, while others in Kagiso and Krugersdorp can engage in the processing, packaging, commercialisation and transport of the agricultural products.

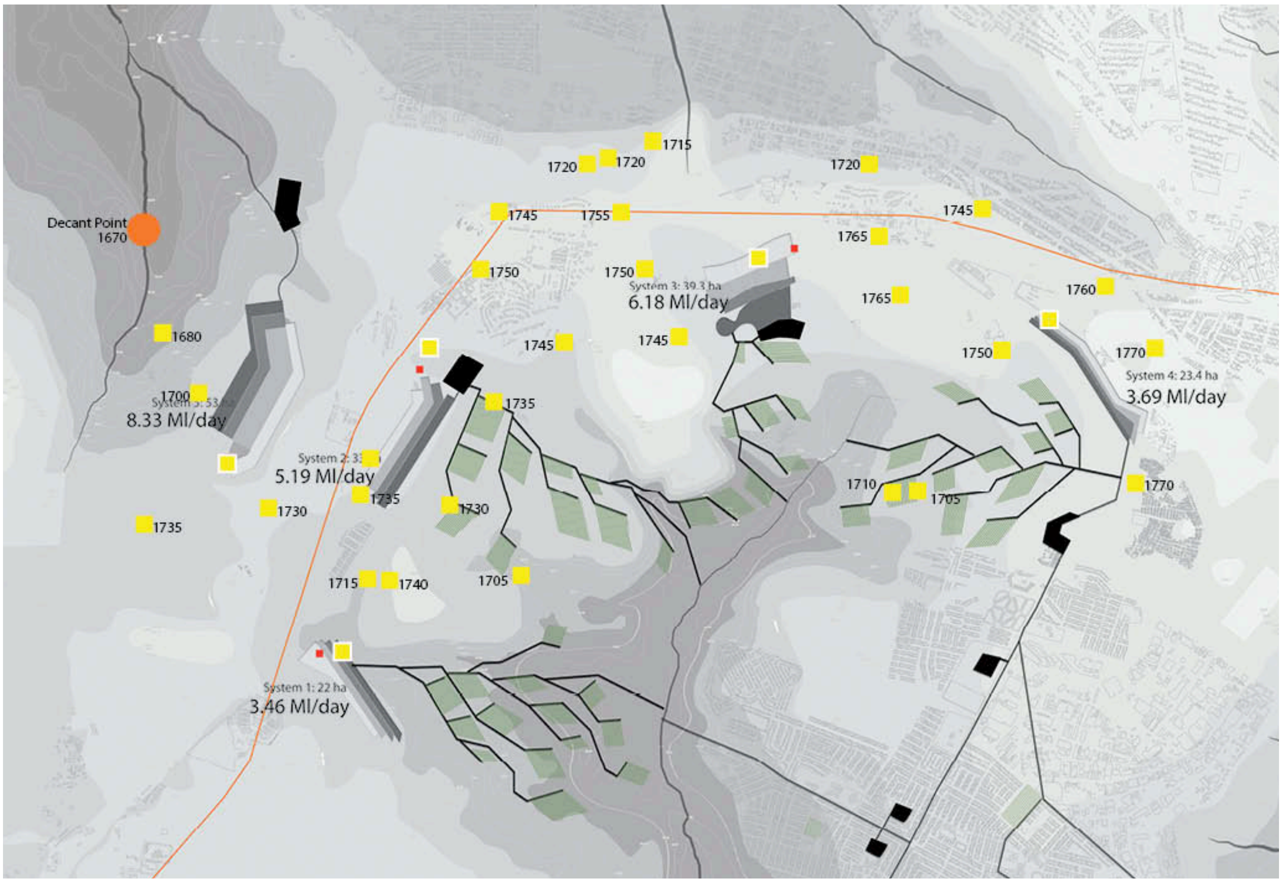

Figure 8 Location of the constructed wetland system in relation to topography and shaft location

There are a number of crops that are suitable for the climate and generate a high added value, e.g. asparagus, strawberries, raspberries, and tomatoes. Taking asparagus as an example: the amount of water available could irrigate as much as 2,000 ha of asparagus land generating an average gross income of R 40,000 / year for more than 23,000 families, as illustrated in Figure 9 (Food and Agriculture Organization United Nations 2014, Department of Agriculture Forestry and Fisheries 2014, Johannesburg Market 2014). Four treatment systems are depicted, showing the treatment of AMD for an agricultural oasis (lighter sections of the image). The squares show the amount of land that can be irrigated according to the crop, and the thickness of the squares indicates its relative income for families (the thickest represents asparagus).

The calculation was made using irrigation requirements for crops from the Food and Agriculture Organization (FAO) of the United Nations and the Department of Agriculture, Forestry and Fisheries (DAFF). Considering the annual rainfall in Johannesburg and the crop rotation, the maximal possible crop surface can be calculated. Considering market prices of asparagus on 06/06/2014, the total income can be calculated, considered as gross income for the families managing and selling the crops. R 40,000 was considered as annual income for the families. This is considered as a simple linear calculation. Using an average of R 60,000 would mean this income would be provided for around 15,000 families. These parameters have a large standard deviation, so numbers are subject to change. What matters is the relative impact that this overall income can have on the people of Kagiso.

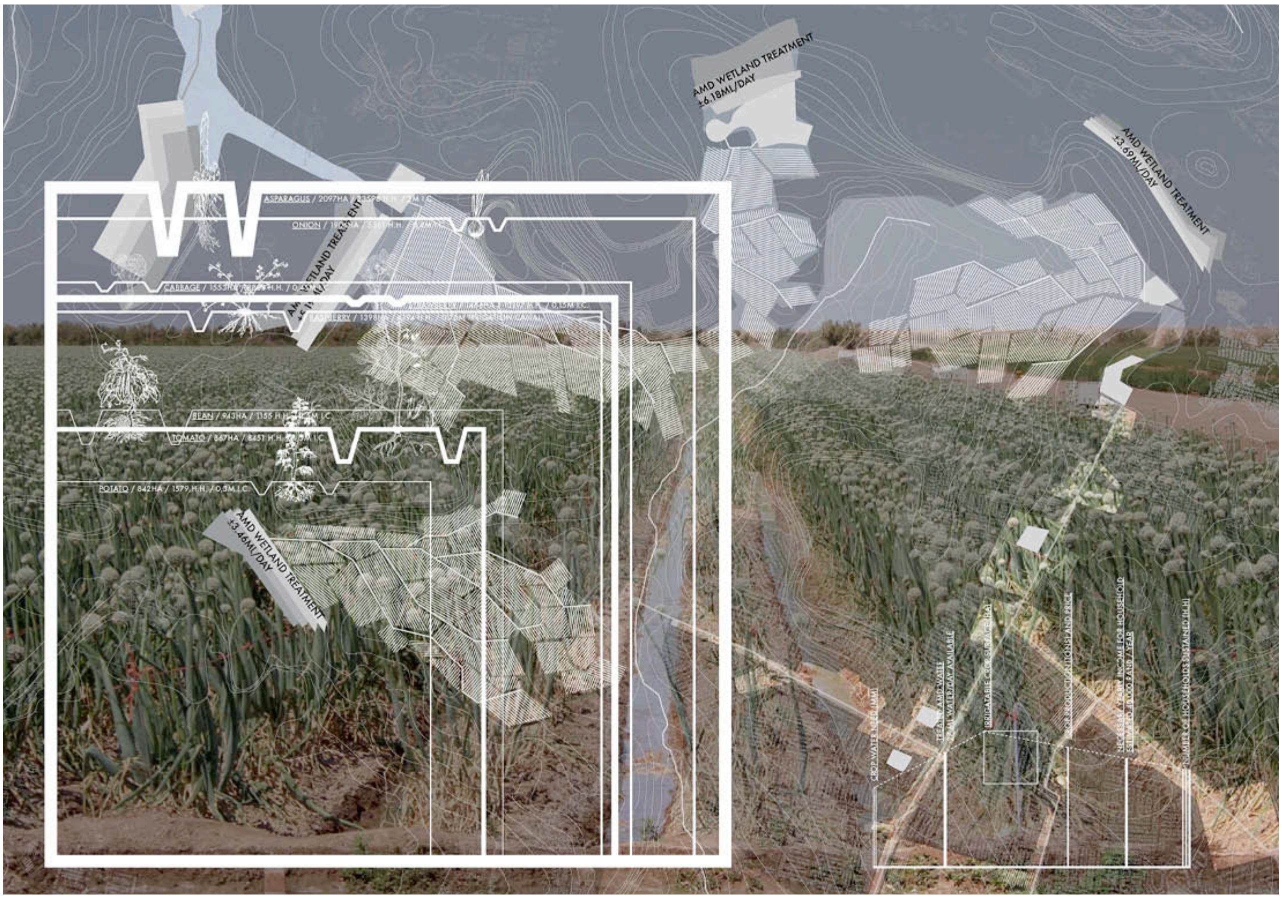

Figure 9 Four treatment systems of AMD for agricultural purposes

4.4 Water cycle closure

The water extracted from underground, half treated and discharged, is now harvested as a commodity and re-cycled on site. In addition, water can become a commodity for any number of things. Bringing water to Kagiso, which historically was deprived of it, should be a priority. Built on the higher plain, the adjacent rivers functioned mainly as buffer spaces for the enclaved population. Introducing abundant water inside the township would be an incentive for alternative practices and economies of various scales. Water for cows, urban agriculture, as public space, etc. Kagiso would be offered an instrument to break loose from its spatial sameness and mono-functionality.

Water could be cycled over and over again (after passing Kagiso it could be treated and re-used again) and would become the incentive for transformation, rather than an annoying by-product of mine activities. Figure 10 shows a project for the constructed wetland and irrigation of agricultural plots in the West Rand, as well as how water becomes a structural element in the organization of a transport and market hub. On the left of the figure, the constructed wetland system feeds the agricultural system downhill. The collection pond also feeds Kagiso with water through a system of canals in the public space, arriving at a large collection pond. This pond organizes the functioning of a multi-modal transport system comprised of train, taxi and bicycle, and also embraces the new market for the locally produced crops.

5 Upcycling the urban

5.1 State of the urban fabric

The problematic conditions generated by the disruption of the soil and water cycles are either creating or aggravating the socio-economic context of the West Rand. The scale of the mining belt goes beyond the scale of the house and even the neighbourhood. Its sheer size makes it the ultimate buffer space between the northern affluent population and poorer, mostly non-white southern population. The southern township of Kagiso is no longer dependent of the mining belt for income, but its configuration – with limited access to services and poor transport options – reduces the income options, as shown in Figure 11. In addition, the fabric is limited by two AMD-affected river valleys, making Kagiso even more spatially enclaved (by poisonous borders) and deprived of public spaces such as the recreational lake in Krugersdorp. In addition, the viability of the municipalities in the West Rand is failing, due to the loss of income from mining-related land uses and rising demands for services in ever more poor communities. Not surprisingly these communities are often located on the borderland or even inside the mining belt.

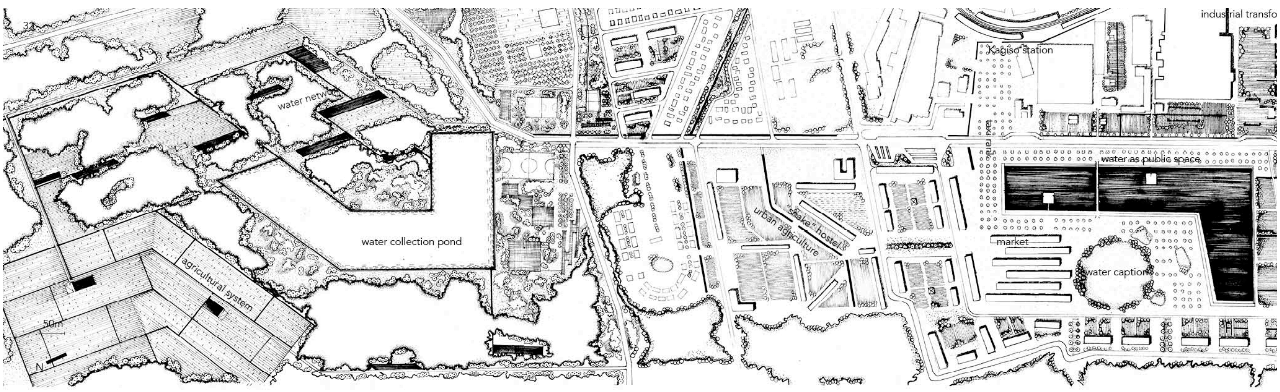

Figure 10 Project for the constructed wetland and irrigation of agricultural plots in the West Rand

The closure of the soil and water cycles finally offers incentives to re-qualify the urban and social structure of the West Rand. The closure of both cycles can only be realized and sustained by the population of the surrounding urban fabric. The reclamation of the mining belt is their affair. The urban conditions are quite poor, especially in Kagiso: a lack of services, almost no public space, oversized but inefficient infrastructure and a monotonous urban fabric composed entirely of the same small overcrowded single-family houses. Kagiso is quite introverted while Krugersdorp is more permeable and is penetrated by the landscape.

5.2 Upcycling the urban: new investment cycle

Kagiso is in need of a new investment cycle. The fabric could be intensified, whilst leaving more space for mixed functions, at least production. Public space also deserves drastic expansion. Introducing abundant water into the fabric, allowing for different urban uses, is seen a catalyst for transformation. The scheme simultaneously speculates on the consequences of a change in the zoning of Kagiso. Inhabitants would be given more building rights (in height instead of accommodating growth with further horizontal expansion), depending on the degree of collaboration they can establish with their neighbours. Such an intermediate organization form could in the long run free up space, make some of the oversized roads obsolete, and intensify urban uses. This in turn allows the landscape generated by closing soil and water cycles to define the new services: a sports field, a soil operation in itself, and agricultural schools. Figure 12 simulates, theoretically, how the introduction of water and vegetation and urban agriculture could instigate the transformation of the edge between Kagiso and the Chamdor industrial platform.

The border between Chamdor and Kagiso, which is an oversized road, lets water and vegetation enter. The presence of a new small-scale economy, e.g. urban agriculture, would allow for new private cooperation structures that intensify the fabric and open up more space for alternative practices and economies. The transformation of the fabric could have a double orientation: when it comes to the open space, it could evolve to the rural rather than the urban; when it comes to housing, an evolution from the low density suburban towards more dense urban fabrics could be enhanced. This double move could allow the population to start appropriating the conditions of the mining belt, while simultaneously generating a housing density that facilitates mixture and makes services more economic. (Irrigated) plots of land for cultivation could be given in a new land redistribution system, reducing the population's dependency on Johannesburg's CBD, while its wider landscape could be tailored as innovative new wildlife tourism, building on an already existing culture, but in an upgraded version that is ready for the 21st century. Therefore, the mining belt's land would enter a new cycle of co-ownership with common facilities that co-manage these types of economies, instead of one entity that holds the rights to this vast land.

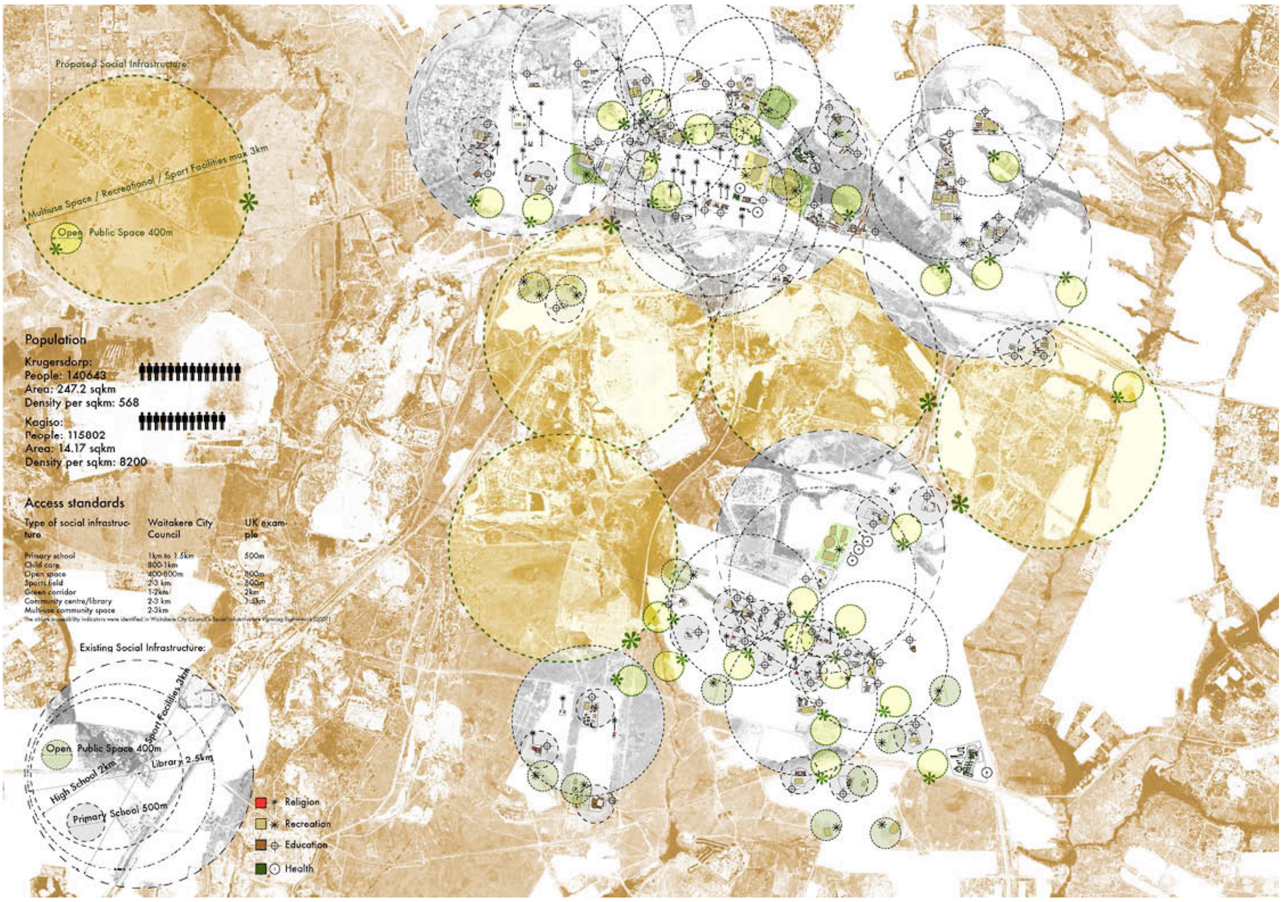

Figure 11 Services in Krugersdorp and Kagiso

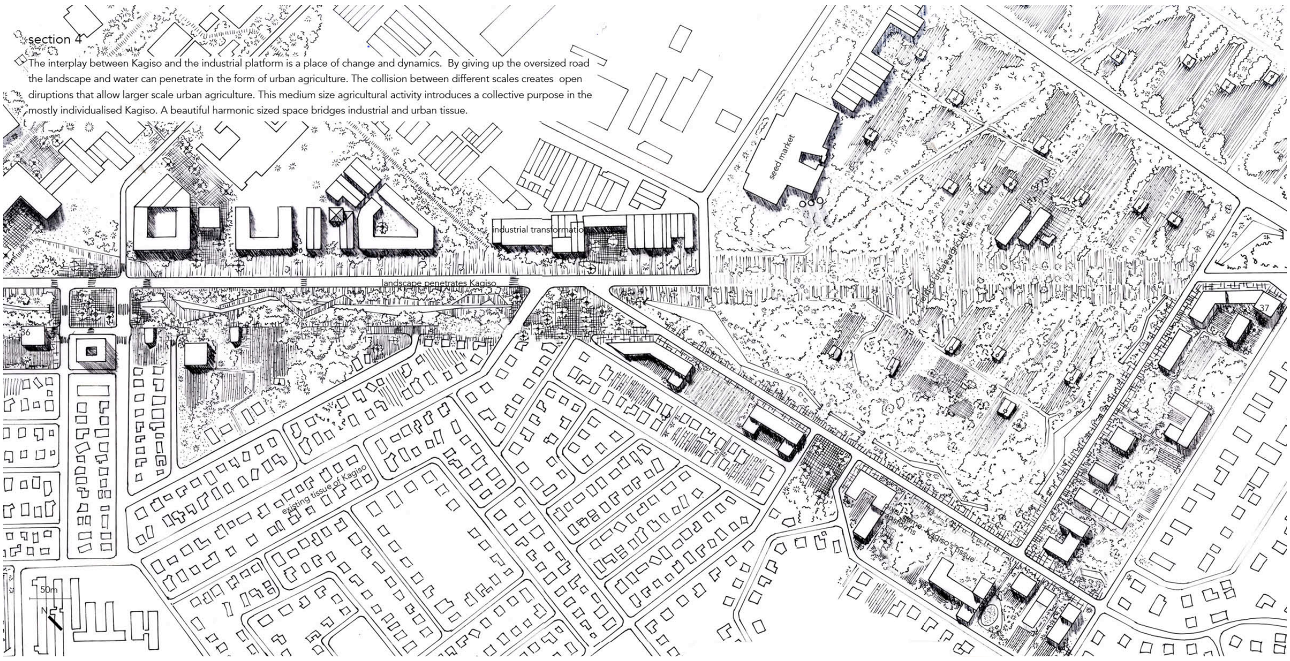

Figure 12 The border between Chamdor and Kagiso

Figure 13 Landscape and fabric mosaic

6 Conclusion

6.1 Embracing the rural identity

The reclamation of the mining belt through lifecycle closure will perforce have to be a joint effort between the mining industry, public authorities and their administrations, and the local communities. Probably such a drastic paradigm shift from 'closure' to 'lifecycle' can only be obtained with serious academic support and open minded engagement from at least mining engineering and life sciences, disciplines such as urban design and planning, social and policy sciences, etc. As a first phase, some of the most critical open ends of the cycles need to be taken care of, i.e. the AMD treatment facilities that need formal pump installations and the treatment system. This supersedes the scale on which the local population can organize itself. The same goes for the instauration of a sustainable soil cycle policy, rather than simply discarding the material. Quite quickly, an incremental and flexible land redistribution system could be organized, allowing a gradual appropriation of the mining belt (turned into domesticated countryside) that would be optimized during execution. Local farmers, cooperatives or other initiative-takers could easily attach themselves to the system, which should be inviting and supportive to begin with. They would be able to dig a canal to tap water, bring in soil for their agricultural activities, use the former mine roads to reach their land and distribute their products. Figure 13 demonstrates intuitively how the region could undergo a metamorphosis and turn into a continuous carpet of rural land-uses and practices, whether these are cow grazing, crop growing, wildlife tourism, urban agriculture, rural settlements. The urban issue would transform and allow the landscape to enter, while the landscape could be appropriated in intermediate size collaborations for small economies. Is it farfetched to imagine that visions for the West Rand, like those developed above, could be helpful in the long process of reformulation of its destiny, including a viable future for its poor population?

6.2 Mine Closure vs. Lifecycle Closure

The soil and water cycle, and urban upcycling, have no final state. Cycles allow for ad-hoc alteration as long as it fits inside the cycle's framework. Cycles that intertwine can generate their own development dynamic, in contrast to mine closure, which is, until now, conceived rather as the carefully engineered devices necessary to obtain a certain outcome. Benefits for the local communities are usually not prioritized in this operation, and are very often present solely in technical and safety terms.

This paper tries to argue that the term "Mine Closure" should be repositioned in the context of "Lifecycle Closure". The landscape left behind by the mine operations is not in need of a "cradle-to-grave" (Swart 2003, p. 490) approach where the grave is carefully considered and then left behind. The mine landscape is in need of a new cycle, a new vision, a new future that is based on seizing lifecycle closure benefits which build on the mine landscape heritage rather than trying to restore it. A next cycle needs to be started, one that finally takes into consideration the ecological and socio-economic parameters, in order to also benefit the local communities of the West Rand.

These principles have been tested through the mechanism of the design studio, using insights drawn from landscape urbanism. The outcome is proposed as a starting point for discussion amongst multiple stakeholders. This is because the concept of lifecycle closure can only work properly if actually practiced or designed through real spatial proposals that are supported by a vision owned by all stakeholders. In this sense, the proposition developed in this paper should only be considered as a hesitating opening move on the board, a starting point to open up discussion, to invite participants with concrete materials. It need not be said that without co-ownership of a vision for the mining belt, it is very difficult for everyone to start co-owning the mining belt in itself. Hence, it is important to set up a process that allows all stakeholders to participate in a vision.

The opening move for such a process could be a quite concrete and hopefully eye-opening proposition, as developed in this paper, which thereafter would be altered and amended so that a common vision crystallizes, after as many rounds of iterations as are required. Thus, a provisional vision formulation has been developed in this paper, and it has been done in the form of an urban design scheme. Urban design has indeed the capacity of communicating both vision and appropriation, to test it and integrate into it all different aspects of closing the cycles. Urban design, when seen as a process facilitator as well as a vision generator and tester, becomes a common platform of negotiation between the stakeholders and the continuous object of change, as insight into the closure of the cycles evolves. Therefore, it becomes a tool of reclamation that is continuously evaluated and updated in an equally cyclic motion.

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